PB-250 550

RESTRICTING DUST EMISSION FROM NATURAL-DRAFT STEAM GENERATORS, CAPACITY 25 TON/HR AND LESS, LIGNITE-FIRED WITH STATIONARY OR MECHANICAL GRATES

Public Health Service

Prepared for:

Environmental Protection Agency

July 1958

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE

BIBLIOGRAPHIC DATA SHEET	1. Report No. APTD-1583	2.	3. Recipient's Accession No. PB250550
4. Title and Subtitle Restricting Dust Emission from Natural-Draft Steam Generators, Capacity 25 Ton/Hr and Less, Lignite-Fired with Stationary or Mechanical Grates			5. Report Date July, 1958 6.
7. Author(s)			8. Performing Organization Rept. No.
9. Performing Organization Name and Address Verein Deutscher Ingenieure Kommission Reinhaltung der Luft Germany			10. Project/Task/Work Unit No. 11. Contract/Grant No.
12. Sponsoring Organization Name and Address U.S. Department of Health, Education, and Welfare Public Health Service Washington, D.C.			13. Type of Report & Period Covered 14.

15. Supplementary Notes

Translation of VDI-Richtlinien 2098

16. Abstracts

The purposes of these specifications are to characterize the influences which create dust; to point out measures for the reduction of dust emissions; to establish guide lines for permissible dust emission; to determine the necessity for dust removal from flue gases and to give indications for the selection of suitable dust removal installations.

17. Key Words and Document Analysis. 17a. Descriptors

Air pollution
Air pollution control equipment
Boilers
Combustion gases
Dust

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

i

PRICES SUBJECT TO CHANGE

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Unlimited	UNCLASSIFIED	24
	20. Security Class (This Page) UNCLASSIFIED	22. Price $3.50-2.25

079011

PB 250 330

VDI-RICHTLINIEN

July 1958

VEREIN DEUTSCHER INGENIEURE	Staubauswurf Dampferzeuger uber 10 t/h Leistung Braunkohlen-Rostfeuerungen Feststehende Roste oder mechanische Roste ohne Unterwind	VDI 2098

APTD - 1583

RESTRICTING DUST EMISSION FROM NATURAL-DRAFT STEAM GENERATORS, CAPACITY 25 TON/HR AND LESS, LIGNITE-FIRED WITH STATIONARY OR MECHANICAL GRATES

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VDI-Kommission Reinhaltung der Luft

Fortsetzung Seite 2 bis 11

VDI-Handbuch Reinhaltung der Luft:
Katalog der Quellen fur die Luftverunreinigung, Ziff. 4.1.1.2.4

REPRODUCED BY
NATIONAL TECHNICAL
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Foreword

This is one of several dozen VDI Clean Air Committee specifications on air purification which the Division of Air Pollution of the U.S. Public Health Service has obtained permission to translate, publish, and distribute in limited quantity. A complete list of the VDI publications being published by the Division of Air Pollution appears on the inside back cover. Because the VDI Committee from time to time revises these specifications, this and other publications in the series may be superseded by later publications.

The VDI Clean Air Committee specifications are compiled by trade or professional associations and published by the Committee. The Committee has neither official status nor regulatory authority, although West German governmental agencies participate in its activities. Air quality specifications published by the Committee are therefore advisory, rather than regulatory. They may however later be adopted by West German governmental authorities.

The English translations were done by the Joint Publications Research Service of the Office of Technical Services, U.S. Department of Commerce. It should be borne in mind that various terms literally taken from the German do not have the same connotation in English; for example, the word "standard" frequently appears where the word "criteria" might better reflect the comparable American meaning, since in this country "standard" is generally meant to imply a legally enforceable value, while "criteria" usually means a recommended value upon which standards may be based.

The publication and distribution of these translations by the Public Health Service constitutes neither endorsement of the specifications nor of the air quality or emission limitations recommended in them. We believe that they contain much useful information that would otherwise not be available to non-readers of German and for this reason have made them available to workers in the air pollution field in the United States.

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Prepared by:

Association of Steam Boiler Owners, Essen
in collaboration with
Technical Inspection Services, Essen.

VDI No. 2098, July 1958

ib

TABLE OF CONTENTS

		Page
	Foreword	1
	Introduction	2
1.	Technology	3
1.1	Guide Values for Standard Furnaces	3
1.2	Classification Range of Raw-Gas Dust	4
1.3	Point of Origin of Dust	5
2.	Reduction of Dust Emission	6
2.1	Dust in Steam-Generator Operation	6
2.2	Selection of Type of Dust Separator	8
2.3	Operating Data of Customary Dust Separators	10
2.4	Pointers for Mechanical Dust Separators	11
2.5	Stacks	11
3.	Guide Lines for Restricting Dust Emission	12
	References	17

FOREWORD

The demands for improved air purification make it necessary to determine the causes of air pollution and to find possibilities of preventing troublesome or noxious substances from being released into the atmosphere. In view of the great number of sources of air pollution, both those responsible for air pollution as well as those affected by it must collaborate on measures for the improvement of existing circumstances. This produces the necessity for an encompassing treatment of all questions and problems of air pollution.

The VDI Committee on Air Purification has assumed the task of determining the sources for air pollution, of collecting technical data on possible reduction of air pollution for each one of these sources and to prepare suggestions for restriction of emission. The findings so obtained are embodied in "Catalogue of Sources of Air Pollution" and in "Specifications".

These specifications on "Dust Emission" contain for each type of installation; first, the technological measures for the reduction of dust content; second, the technical possibilities for dust precipitation; and third, a suggestion for the restriction of dust emission. The code number shown on the right lower cover sheet refers to the "Catalogue of Sources of Air Pollution" (VDI Specifications No. 2090).

The committee will adapt the specifications to the progressive development of technological and technical findings. These specifications and other technical documentation of the VDI Commission on Air Purification" form the content of the "VDI Manuel on Air Purification", the arrangement of which will be published at a later date.

INTRODUCTION

It is the task of the specifications on "dust emission":

1) to characterize the influences which create dust;
2) to point out measures for the reduction of dust emission;
3) to establish guide lines for permissible dust emission;
4) to determine the necessity for dust removal from flue gases and to give indications for the selection of suitable dust removal installations.

Knowledge of the relation between emission and deposition is important for an objective evaluation of the dust level. Present research findings give many indications on this relation (1-4) but the evaluation of given circumstances is made very difficult by multiple factors.

Only accurate and comparable measurements provide reliable data for correct evaluation. Measurements must be carried out by experts according to the VDI Specifications on Efficiency Tests for Dust Separators (5).

The determination of the permissible emission from an installation depends to a large extent on the conditions in the area and can therefore be effected only on the basis of measurements which take into account also prior existing load factors.

These specifications are applicable only to newly designed installations. Gaseous emissions including sulphur-dioxide are treated in the specifications on "Gas Emission".

1. Technology

1.1 Guide Values for Standard Furnaces:

The following indicates average values but individual steam generators have been designed for dimensions and conditions which differ essentially from the data below:

a) Lignite-fired furnaces with natural draft and stationary or mechanical grates	Medium-size steam generators, capacity 25 ton/hr and less
b) Fuel range	
All grades of coal	Grades of lignite
Grain size	10-80 mm or coal as extracted with least possible share of fine grains.
Volatile components (related to pure coal)	50-60%
Ash content (13) (related to moist coal)	2-4% (furnace not suitable for higher ash content)
Sulphur content (related to pure coal)	0.5-4%
Water content	40-63%
Calorific value	1,600-2,800 kcal/kg
c) Grate-surface loading (2, 12)	400,000-600,000 kcal/(m^2/hr)
d) Secondary air (2, 12)	Generally none, occasionally up to 10% of combustion air
e) Preheating of air (2, 12)	Generally none

(continued)

(Continuation of table)

f) Flue gases at smoke box	
Temperature	200-300°C
CO_2-content	12-16%
Specific flue-gas volume (avg. values in relation to coal; 6)	At calorific values of 2,800 1,900 1,600 respectively 5.5 4.7 4.1 Nm^3/kg
Dust content in raw gas (related to moist gas)	1.5-7.0 g/Nm^3 and more, depending on load, furnace operation, share of fine grains in fuel and content of incombustibles (latter up to 40%)
Dust classification in raw gas	Cf. Fig. 1
SO_2-content in raw gas	Cf. Specifications on sulphur dioxide

1.2 Classification Range of Raw-Gas Dust

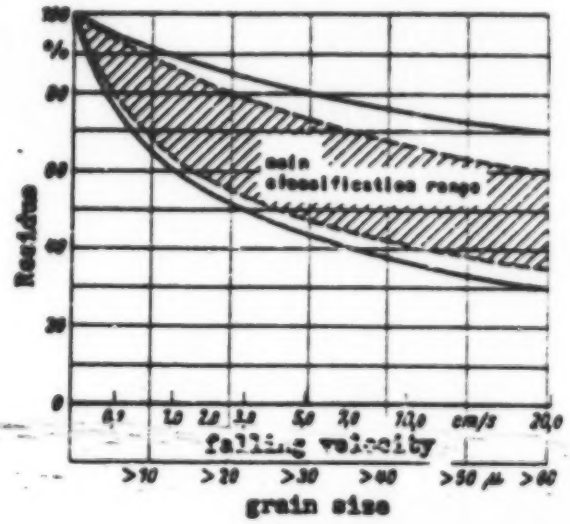


Figure 1. Classification Range of Raw-Gas Dust from Lignite-Fired Furnaces with Stationary or Mechanical Grates and Natural Draft.

(Primary measurements are the falling velocity in air and the grain sizes so calculated are valid only for spherical particles of the specific unit weights $\gamma = 2\ g/cm^3$.

1.3 Point of Origin of Dust

(Diagram of a steam generator with Lignite-fired furnace with stationary or Mechanical Grates and Natural Draft)

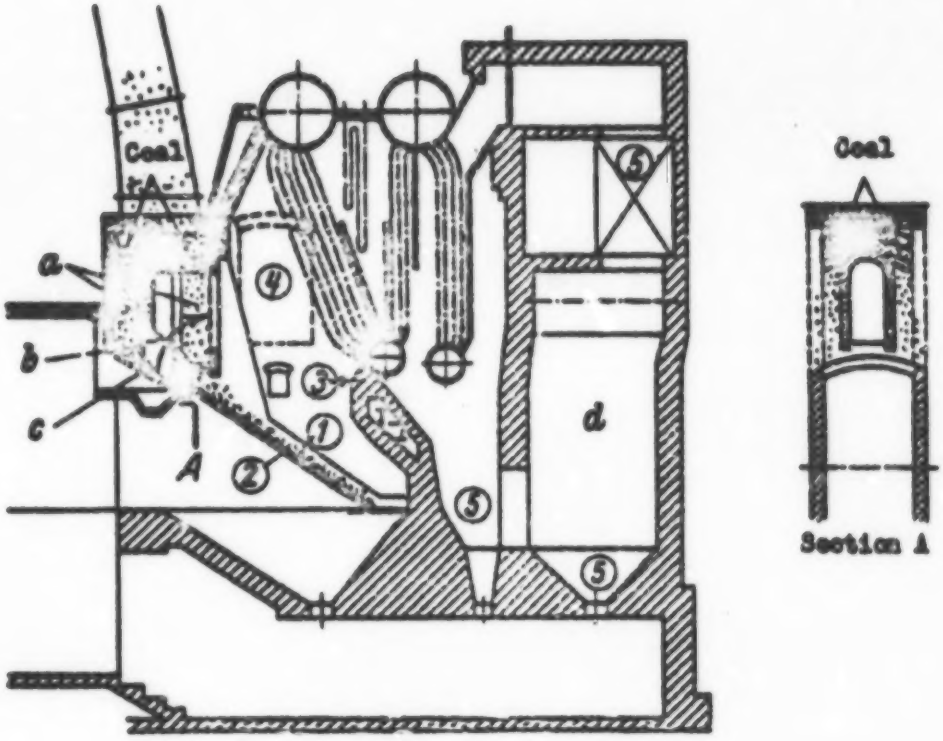


Figure 2. Diagram of Steam Generator with Lignite-Fired Furnace with Stationary or Mechanical Grates and Natural Draft *

1 - fuel bed
2 - combustion air
3 - secondary air
4 - combustion chamber
5 - secondary heating surfaces and dust collector

a - pre-drying chamber
b - coal-flow regulator
c - coal chamber
d - gas flue to stack and/or dust separator

* Numerous other boiler designs and combinations of boiler and dust separator differ from this representation.

2. Reduction of Dust Emission

2.1 Dust in Steam-Generator Operations:

In regard to dust removal, the conditions listed below are:

Point of Origin (Cf. Fig. 2)	Increasing	Reducing
Fuel bed ①	High share of fines in coal; high ash content, high share of lignite.	Combustion of screened coal; low ash content.
	Non-uniform bed height and grain distribution on grate; layer height on grate too low.	Careful control of correct and uniform fuel charging; correct air distribution and draft regulations.
	Formation of ribbons during combustion due to incorrect charging of fuel; formation of clinker; grate-surface loading too high.	
	Inappropriate grate cover; grates too short.	Correct selection of grate cover suitable for given type of fuel.
	Slope of grate too much or too little.	
	Incorrect manual or mechanical stoking.	Throttling of draft while stoking.
Combustion air ②	High air velocities in fuel bed; high intensity of draft and forced-draft pressure, high grate-surface loading, overloading.	Intensity of draft adapted to fuel classification and layer height in order to prevent coal particles from being blown out.
	Poor air distribution, high excess air and non-uniform grate covering.	Most favorable excess of air.

(continued)

(continuation)

Point of Origin (Cf. Fig. 2)	Increasing	Reducing
Secondary air ③	Incorrectly directed admission of secondary air with high turbulence over fuel bed.	Aerodynamically and thermodynamically correctly admitted secondary air with adequately high temperature for proper combustion of suspended fuel particles; distribution into many streams of high velocity; prevention of turbulence above fuel bed.
Combustion chamber ④	Unfavorable flow conditions of flue gases; inappropriate flow channels or other restriction and excessive gas velocity; rising velocity too high, inadequate dimensions of combustion chamber, unfavorable combustion intervals.	High combustion chamber, correct air-flow design of necessary ignition and recirculation ducts; adequately high and wide combustion chambers.
Secondary heating surfaces and dust collector ⑤	Unfavorable flow conditions in boiler flues. Inappropriate and leaking dust collectors. Leaking closures may cause already precipitated dust to be entrained.	Air-flow conditions most favorable for dust precipitation in boiler and smoke flues, aided by baffles, bends and changes in cross section. Large dust collectors with strongly sloped sliding surfaces. Effective closure of dust-discharge traps (under favorable conditions, 85-85% of dust remain in clinker and in dust collectors).

(continued)

(continuation)

Point of Origin (Cf. Fig. 2)	Increasing	Reducing
⑤	Failure to empty dust collectors at proper time.	Observance of scheduled discharge intervals and careful maintenance of discharge traps.
	Dust clouds when activating soot-blower and ball-rain installations.	Activation of soot-blower and ball-rain at low load whenever possible.
	Neglecting removal of dust from any existing smoke flues and at the stack.	Provision of proper precipitation and removal conditions for dust also in any existing smoke flues and at the stack.
Dust separator ⑥	Cf. Section 2.3 and 2.4.	

2.2 Selection of Type of Dust Separator

The following data influence the selection of the type of separator:

a) Type of construction and capacity of steam generator and furnace installation, installation with or without fly-ash recirculation;

b) Characteristics of the fuel (volatile components, ash content, ash behavior);

c) Amount, grain classification and characteristics of raw-gas dust;

d) Available space for dust separator (6);

e) Stack height;

f) Permissible emission.

Points a, b, c influence the volume and dust content of raw gas; point f depends among others on conditions in the vicinity, on orographic and metereological factors, on prior loads and on point e (Cf. Sec. 3). Selection of the type of separator therefore requires a balance between magnitudes e) and f) in consideration of d) (7).

The design of the dust separator and/or its over-all efficiency rate is not exclusively decisive for the rate of emission. In one and the same dust separator and/or at the same efficiency rate, emission from the stack will reach higher values when the raw-gas dust content increases. In large installations and with a high ash content of the coal, it may therefore become difficult to reduce emission from the stack, through selection of a high grade separator, to the desired degree whereas, at a low raw-gas dust content, adequately low emission may already be attained by utilisation of a simple dust separator. The raw-gas dust content and amount is especially influenced by the data listed under points a and b. For the selection of the type of separator, the points a, b, c are therefore particularly important.

Measurement of dust content in raw and purified gas should be carried out according to VDI Specifications (5) and suitable measurement distances and instruments taps should be provided in the design of the installation.

In order to prevent later discussion, it is recommended to settle all questions important for dust removal from pure gases between the future operators, suppliers and inspection services already during the planning of new installations. This includes agreement on the method of dust analysis (blast sorting or sedimentation analysis including selection of the sedimentation fluid); the CO_2-content or the flue-gas volume per unit of time at the point of measure must be agreed upon at the same time as the determination of the maximum permissible dust emission in g/Nm^3 (in relation to moist gas) for a given steam production (ton/hr).

The correct wording of the guaranties for the efficiency rate of the separator is of great importance and the guaranty given must be demonstrable in each case. It is recommended not to base the guaranty on efficiency rates with too many decimal points (1, 2, 5, 8).

Of further importance is careful observance of the operating instructions of the supplier of the separator and proper control and maintenance of the separators in operation (Cf. Sec. 2.3 and 2.4).

The specifications for placing orders for dust-removal installations of the Association of Steam Boiler Owners in Essen must also be taken into account (these will probably be published during 1958).

2.3 Operating Data of Customary Dust Separators:

The following table contains average values for properly maintained dust separators and the purpose of utilization given here is valid only for grate-furnaces.

Separator System	Maximum efficiency rate +) %	Limit of precipitation ++) Falling velocity cm/sec	Limit of precipitation ++) Grain size in μ o)	Draft required mm H_2O	Main utilization
1. Dust chambers					
1.1 Without baffles		Not sharply separable			For low demands and very coarse dust.
1.2 With baffles	30-50			3-6	
2. Centrifugal					
2.1 With cyclone	70-90	5.4-13.5	30-50	25-50	In normal cases
2.2 Simple cyclones (large dia., low height).	50-90	13.5-30.0	50-100	20-40	
2.3 High-efficiency cyclone (single and multiple elements)	85-97	0.6-5.4	10-30	50-80	For high demands and difficult fuels.

+) Depends largely on type, content, and fineness of dust, grain shape, gas and operating conditions. The maximum efficiency rate alone is no sign of quality for the separator and by itself gives no indication on the prevention of dust emission (Cf. Sec. 2.2 and references 1, 2, 5, 7). The indicated efficiency rates are applicable to new dust-removal installations. After long-continued operation, the guarantied efficiency rate should not drop more than 2 points.

++) Limit of precipitation: Grain size above which particles are precipitated nearly entirely.

o) Primary measurement are the falling velocities in air from which the grain sizes so calculated are valid only for spherical particles of the specific unit weights γ g/cm^3.

2.4 Pointers for Mechanical Dust Separators:

For operational efficiency, conditions listed below are:	
Unfavorable	Favorable
High share of fine grains in raw-gas dust (Cf. Fig. 1).	Separator for special cases
Non-uniform loading of several parallel cyclones.	Uniform distribution of flue gases to several parallel aggregates and proper air-flow design of raw-gas ducts.
Non-adjustable separator for partial or overload. When adjustable, incorrect adjustment of load.	Shut-down of one or more aggregates under partial load.
Internal leakage due to wear, bypasses between individual cyclone or separator cells.	Proper maintenance and frequent inspection of parts subject to wear and suitable lining when necessary.
Clogging of cells and dust discharge traps of individual cyclone and separator cells. Leaking valves and traps, especially of dust-discharge devices.	Prevention of temperature drop below dew point. Continuous control of measurable operating data of separators, e.g. pressure drop and energy consumption (changes in values generally indicate defects and errors).
Wrong dimensions of separator (efficiency rate depends on flue-gas throughput).	Correct dimensions of separator for normal steam-generator load.

2.5 Stacks:

The following are decisive for the height and number of stacks:

1) Specifications on restricting sulphur dioxide emission (Cf. applicable VDI Specifications);

2) Specifications on restricting dust emission (Cf. Sec. 3).

Aside from creating the necessary draft, one of the main purposes of the stack is to discharge gas and dust as high up as possible above the surface of the ground and to produce thereby a reduction of the ground concentration of such discharges through better distribution of the smoke streamer (3, 4).

This is achieved by:

a) Stacks as high as possible (10, 11);

b) Discharge velocities of waste gases at the top of the stack as high as possible (10, 11);

c) Maximum possible exploitation of the thermal lift of the smoke.

Cf. a) The lower limit of stack height is given by Sec. 3 of the Specification on restricting sulphur dioxide emission. In regard of the immediate neighborhood, experience indicates that the top of the stack should be not less than 1.7 times as high as the highest building in the immediate vicinity (10, 11).

Cf. b) At the same waste gas temperature, greater thermal lift is produced by a large-diameter stack -- due to lesser cooling of the smaller surface -- than by distributing the same volume of flue gases over several stacks of smaller diameter. Discharge of flue gases of several steam generators through a stack with a large diameter may therefore be more advantageous than an arrangement of several stacks of smaller diameters. In determining the diameter of the stack, however, partial load factors must be taken into consideration.

3. Guide Lines for Restricting Dust Emission

The following conditions must be taken into consideration for newly designed installations (9, 10, 11, 12);

1) Restriction of Emission on the Basis of Deposition:

The emission of dust by an installation should be restricted on the basis of the permissible amounts of deposition in the vicinity and by the conditions of distribution given by the location and type of construction of the plant (stack height, adjacent emitters, orographic position, etc.). The existing and permissible dust level of the area should be included therein (this manner of determining the restriction of emission by deposition takes into account the natural laws of the relation between emission, distribution and deposition. Details of the

method should be based on the latest technical findings. The VDI Committee on Air Purification issues special instructions in this regard.)

2) Restriction on the Basis of Given Technical Factors:

In as far as the above condition does not make higher demands for the purity of waste gases, provision should be made for a technically and economically defensible installation corresponding to the type and capacity of the plant for reducing the dust content of purified gas. The maximum permissible dust emission for such an installation is given in the diagram herein as a function of the total ash introduced with the fuel.

Instructions for Utilization of Diagram

The following symbols in the diagram (9) designate:

A_m - total ash in ton/hr introduced into furnace at maximum steam production

σ_s - maximum permissible emission through stack as percent of Am

a_f - ash content of moist coal in percent;

a - ash content of dry coal in percent;

H - stack height in m

$Am \cdot \sigma_s = S_s$ maximum permissible absolute emission from stack in ton/hr.

The solid lines of the diagram indicate the maximum permissible emission by the stack(σ_s) in percent of total ash(Am)introduced in double-logarithmic representation. In view of the necessity for utilization of fuel with high inert content, the ash content(a)has been introduced as a parameter.

For the determination of the maximum permissible emission by a steam-generating installation, the ash total introduced with the fuel (Am)is determined in ton/hr from the total fuel calculated for a given steam production and from the ash content, a_f, of the fuel. The permissible dust emission σ_s and/or S_s then results from the following example:

Example:

Steam production = 10 ton/hr; a_f = 3%; a = 7.9%; fuel consumption = 4.72 ton/hr; Am = 4.72 · 0.03 = 0.14 ton/hr.

The curve for parameter(a)less than 20% shows σ_s = 8.3% as ordinate for Am = 0.14 ton/hr.

From this follows as maximum permissible absolute emission by the stack:

$S_s = Am \cdot \sigma_s = 0.14 \cdot 0.083 \approx 0.0116$ ton/hr = 11.6 kg/hr.

The particular given content of incombustibles must be considered in the selection of the dust separator.

The broken lines below the straight line σ_s = 4% are intended to give indications for the higher requirements for dust removal necessary at lower stack heights.

The values for σ_s determined from the diagram by means of the examples above must be maintained. How these emission values are achieved is left to the discretion of the designer or purchaser of the steam-generating installations. Possibilities are offered by boiler design, ash fusion, method of firing and selection of dust-removal installations.

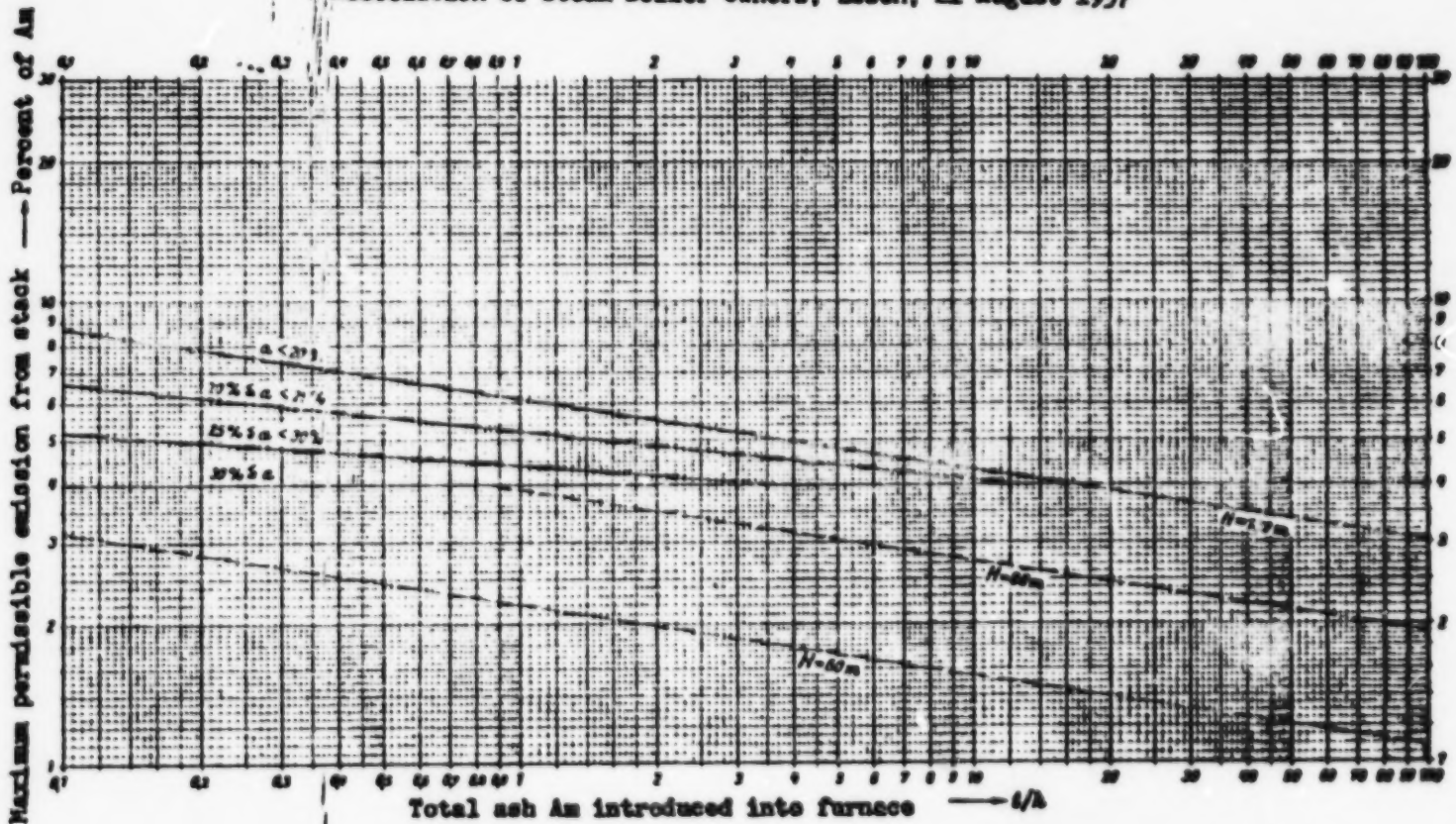
Supplement to Diagram

All newly designed steam-generating installations fired with ash-containing fuels (in the determination of the ash total Am introduced, the entire steam-generating installation must be considered as a unit) shall be equipped with dust-removal installation which must be designed according to the conditions for restriction of emission established by the diagram herein and in Sec. 3, subsec. 2, unless Sec. 3, subsec. 1 does not make other demands. Only such dust-removal installations should be constructed which correspond to the latest technical developments.

The σ_s values resulting from the diagram herein assume that the rates of fusion and dust precipitation are attained on which the order was based. The corresponding values must consequently be guaranteed by the supplier. In the operation of the installation, a certain tolerance from these guarantied values should be established in each case. If the guaranty values are not confirmed by acceptance inspection, the supplier shall be required to make the necessary changes and alterations.

If in individual special cases the requirements of the diagram for restriction of emission cannot be maintained in operation by reason of particular factors which could not be anticipated in planning, exceptions shall be authorized only then when the dust-removal installation was designed by incorporation of the latest technical developments.

Restriction of Dust Emission from Newly Designed Installations
Association of Steam Boiler Owners, Essen, 21 August 1957


Maximum permissible emission from stack —— Percent of Am
a < 20 %
20 % ≤ a < 35 %
35 % ≤ a < 50 %
50 % ≤ a
H = 150 m
H = 60 m
H = 40 m
Total ash Am introduced into furnace —— t/h

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11. Cf. 1-, p. 504/505.

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13. F. Münzinger: Steam Power, 3rd Ed., Berlin 1949, p. 22.

Note: Numerous further references are contained in the above literature.

VDI CLEAN AIR COMMITTEE SPECIFICATIONS, PUBLISHED IN ENGLISH BY THE DIVISION OF AIR POLLUTION, U.S. PUBLIC HEALTH SERVICE

VDI No.	Title
2090	Sources of Air-Polluting Substances
2091	Restricting Dust Emission From Forced-Draft Boiler Installations, Capacity 10 Ton/Hr and Over, Hard-Coal Fired with Mechanical Grates
2092	Restricting Dust Emission From Forced-Draft Boiler Installations, Capacity 30 Ton/Hr and Over, Hard Coal-Dust Fired with Dry Ash Removal
2093	Restricting Dust Emission From Forced-Draft Boiler Installations, Capacity 30-600 Ton/Hr and Over, Hard Coal-Dust Fired with Liquid Ash Removal
2094	Dust Prevention - Cement Industry
2095	Dust Emission From Induced-Draft Ore-Sintering Installations
2098	Restricting Dust Emission From Natural-Draft Steam Generators, Capacity 25 Ton/Hr and Less, Lignite-Fired with Stationary or Mechanical Grates
2099	Restricting Dust Emission in Blast-Furnace Operation
2101	Restricting Dust Emission From Copper-Ore Smelters
2102	Restricting Emission of Dust From Copper-Scrap Smelters
2103	The Restriction of Chlorine Gas Emission
2104	Terminology in Air Purification
2106	Permissible Immission Concentrations of Chlorine Gas
2107	Permissible Immission Concentrations of Hydrogen Sulphide
2108	Permissible Immission Concentrations of Sulfur Dioxide
2109	Restricting Emission of Hydrogen Sulphide and Other Sulphur-Containing Compounds, Except Sulphur Dioxide, From Gas Generators in Coke, Gas, and Coal-Constituent Processing Plants
2110	Restricting Emission of Sulphur Dioxide From Coke Ovens and Gas Plants
2115	Restricting Emission of Dust From Manually Operated Central-Heating Boilers, Capacity 600,000 KCAL/Hr and Less, Fired with Solid Fuels
2281	Restricting the Emission of Fumes From Diesel-Engine Vapors
2284	Restricting Emission of Dust and Sulphur Dioxide in Zinc Smelters
2285	Restricting Dust and Sulphur-Dioxide Emission From Lead Smelters
2290	Restricting Emission From Gas Generators in Coke and Gas Plants
2292	Restriction of Dust Emission in Anthracite-Briquet Factories
2293	Restricting Emission of Dust in Anthracite Processing Installations
2302	Restricting Emission of Dust, Tar Mist and Gas when Charging Coke Ovens
2105	Permissible Concentrations of Nitrous Gases

GPO 889-179